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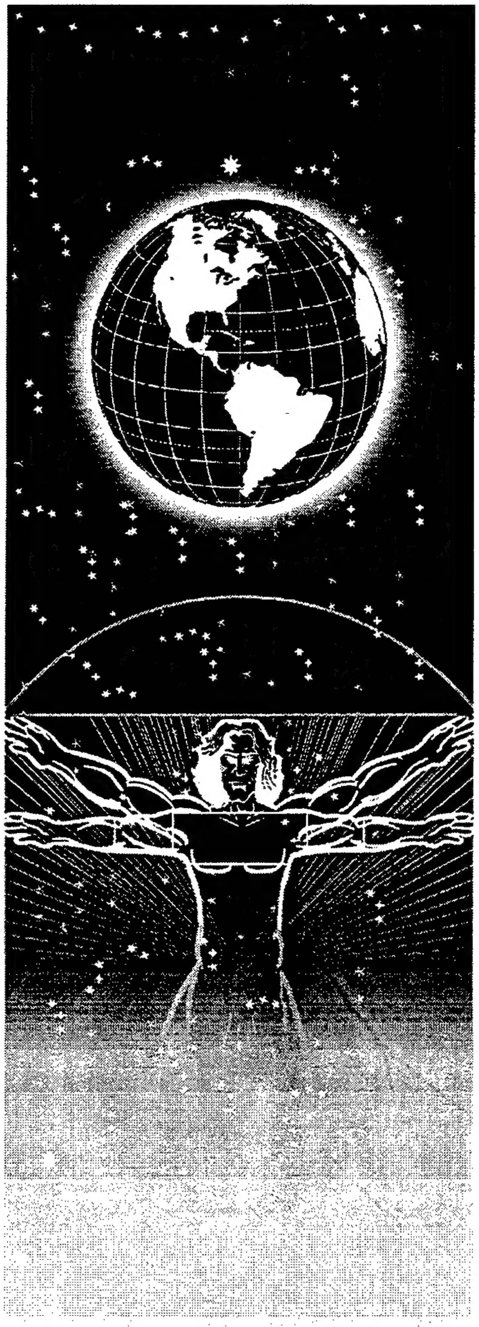

UNITED STATES AIR FORCE
ARMSTRONG LABORATORY

Evaluation of Potential Indoor Air Impact of TCE in Groundwater on Building 864, Air Force Plant 44, Arizona

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October 1997

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Occupants of a building proximate to a site where a hazardous substance release has occurred may potentially be exposed to the released chemicals from their transport into the indoor environment. The Air Force Center for Environmental Excellence (AFCEE) requested Armstrong Laboratory's Environmental Sciences Branch evaluate transport through ambient air at Building 864, Air Force Plant 44, Arizona. The evaluation uses the Farmer model, as described in EPA guidance EPA-451/R-92-002, "Assessing Potential Indoor Air Impacts for Superfund Sites", to predict potential indoor air concentration. This indoor air concentration was then used in the EPA's Risk Assessment Guidance for Superfund algorithm to predict potential excess cancer risk to workers in the building.

14. SUBJECT TERMS

Trichloroethylene	Risk assesment	AFCEE
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INTRODUCTION

This report evaluates the potential indoor air impact of trichloroethylene (TCE) soil gas to workers in Building 864 at Air Force Plant 44 (AFP 44) in Tucson, Arizona (Fig. 1). TCE is present in the groundwater beneath Bldg 864. TCE can volatilize from the groundwater and move up through the soil column as a gas and can potentially move into buildings such as Bldg 864. This evaluation models potential indoor air concentrations based on the diffusion of TCE from groundwater and uses this modeled air concentration to assess cancer risk and potential non-cancer effects to workers in Bldg 864 and to workers and passers-by outside the building.

Background

Captain Patrice Melancon, Air Force Center for Environmental Excellence (AFCEE) team chief for AFP 44, requested the Environmental Sciences Branch at Armstrong Laboratory (AL/OEMH) evaluate potential indoor air exposures to TCE in soil gas in Bldg 864. The building is located near an inactive landfill, used from approximately 1955 until the late 1960's or early 1970's (Fig. 2). As AFP 44 is part of the larger Tucson International Airport Superfund Site (TIASS), EPA Region IX and the state of Arizona have requested this evaluation. Rather than use actual air data from Bldg 864, USEPA Region IX and the Arizona Department of Health Services (ADHS) instructed the Air Force to use soil gas data. Using EPA guidance and assumptions recommended by Mr. Craig Cooper, EPA Region IX Superfund Office, and Mr. Will Humble (Ref 5,7), ADHS, we modeled potential indoor air impact from soil gas generated by the TCE groundwater plume moving below the building.

Site 2, the Final Assembly and Checkout (FACO) Landfill, is an inactive landfill being remediated through AFP 44's Installation Restoration Program (IRP) (Ref 2). Bldg 864 is located southeast of the landfill (Fig. 2). Groundwater below the site moves generally to the northwest, but the TCE plume is moving radially from the landfill, probably due to the groundwater reclamation system in the regional aquifer upper zone. Further examination shows TCE groundwater concentrations in the regional aquifer upper zone below Bldg 864 to range from 5 ug/L to 200 ug/L.

Sampling Locations and Soil Gas Data

Recent soil gas monitoring data was collected from the extensive soil vapor extraction (SVE) system maintained by Earth Tech (Fig. 3). Three to four sets of data have been collected from the system between October 1996 and April 1997 (Appendix 1). Per guidance from ADHS (Ref 8), we have considered only soil gas concentrations from the shallow strings of the SVE system (those closest to the surface) at a radius of approximately 200 feet from Bldg 864 (Figure 4). This allows us to consider potential impact on workers in the building as well as considering potential impact on workers or passers-by outside the building.

Mr. Jim Craghead, Environmental Project Manager at AFP 44, provided a diagram with dimensions of Bldg 864 (Fig. 4). He calculated an area of 27236 ft^2 with a total volume of 390976 ft^3 (Ref 6). For conversion to metric units, we assumed the area to equal a box with length of 272.36 ft and width of 100 ft.

Eight sampling ports fall within a radius of 225 feet of Bldg 864 (Figure 5 and Appendix 1). (We selected 225 ft rather than 200 ft because of the ease of use of the scale in Figure 4.) Using EPA guidance (Ref 12), we calculated the 95^{th} UCL on the mean of the concentration for all data from the eight sampling ports to be 344 ug/L. This is a conservative estimate because the November 1996 sampling round resulted in high detection limits (due to laboratory operations) of 273 ug/L. In the absence of better data, we used half the detection limit in our calculations, 136.5 ug/L, which appears to be high (conservative) when compared to other values at each sampling port. Subsequent analyses produced detection limits as low as 3 ug/L.

METHODS

To be consistent with other EPA and state efforts at AFP 44 and the TIASS, we used the Farmer model for calculating emissions from chemicals dissolved in groundwater (Ref 13). The Farmer model can be used for estimating emissions from chemicals dissolved in groundwater and for contaminated soils. We converted flux to potential indoor air concentrations, which were substituted into EPA's intake equations found in the "Risk Assessment Guidance for Superfund" (Ref 10). From this, we calculated the potential human excess cancer risk using the Region IX toxicity value (inhalation slope factor, SF_i) for TCE and the non-cancer hazard quotient using the reference concentration (RfC).

To assess potential risk to workers outside the building, we used the box model, estimating the size of the box using the 200 feet length from each side of the building as a guide. Other parameters will be discussed later.

Flux Calculation And Indoor Air Estimation Calculation Assumptions

The Farmer model calculates the flux rate of the chemicals as a result of diffusion of vapor through the soil matrix. Flux is calculated in grams per second per square centimeter at the point of exit—in this case, the point of exit is Bldg 864. Once flux is determined, the indoor air concentration can be easily calculated and the concentration can be used to estimate risk using standard USEPA methods.

Below are the flux calculations and the estimation of both indoor and outdoor air concentrations. For indoor air concentration, ADHS recommended that we use F=0.001. F, which represents the fraction of the floor through which soil gas can enter, is a limiting factor which shows a soil gas reduction into the building. This assumes that the concrete floor in Bldg 864 provides a barrier to the soil gas—if there were no barrier, we would use F=1, meaning all the soil gas would diffuse into the building.

For outdoor air concentration, there is no barrier assumed. We calculated the width of an imaginary box perpendicular to the predominant southeast wind direction to be 712.5 ft. We calculated two mixing layers to estimate exposure to workers and passers-by outside Bldg 864. ADHS recommended a mean annual wind speed of 2.6 m/s and a mixing zone height of 10 m.

Figure 1--Location of Study Sites

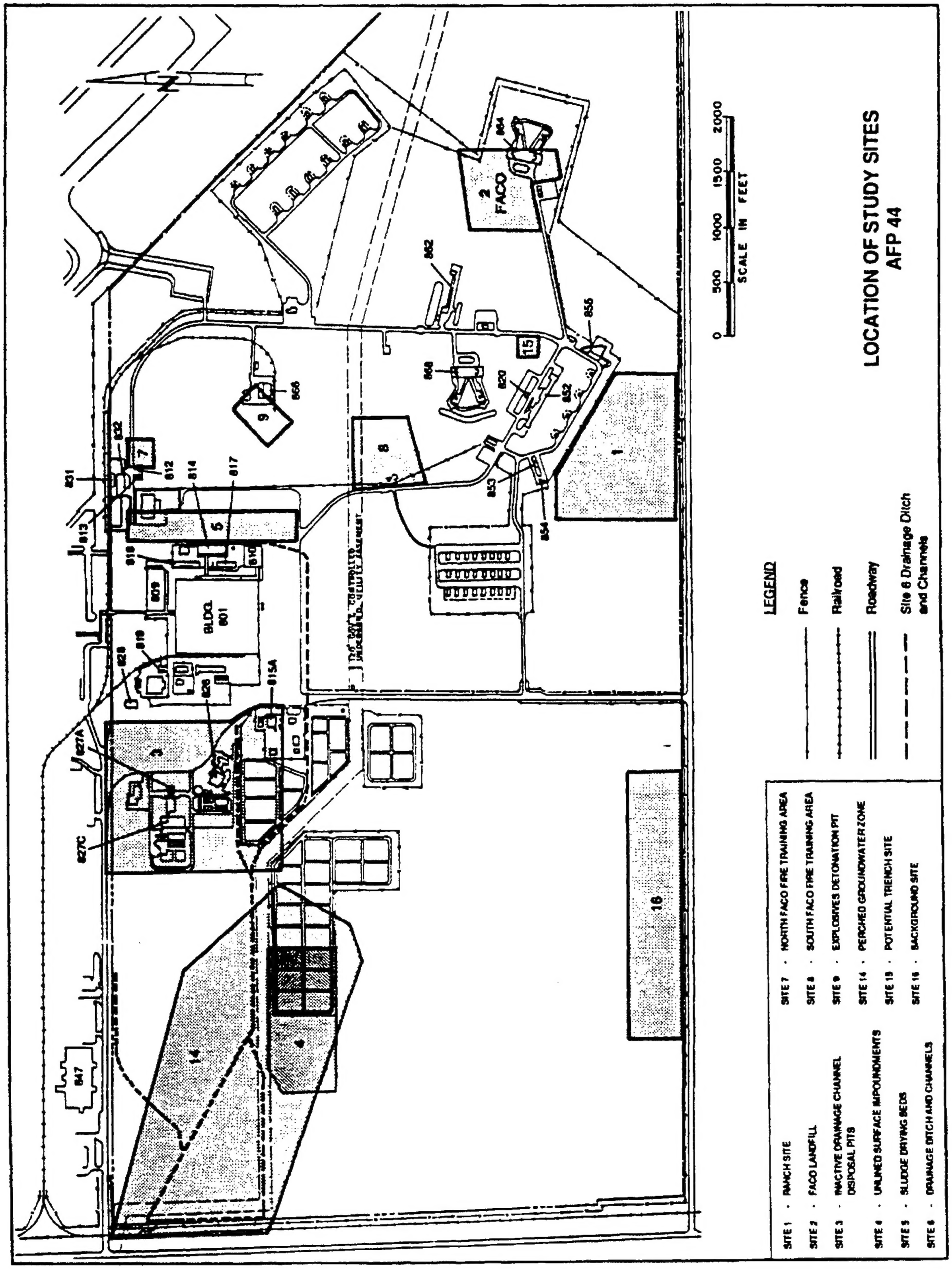


Figure 2--FACO Landfill

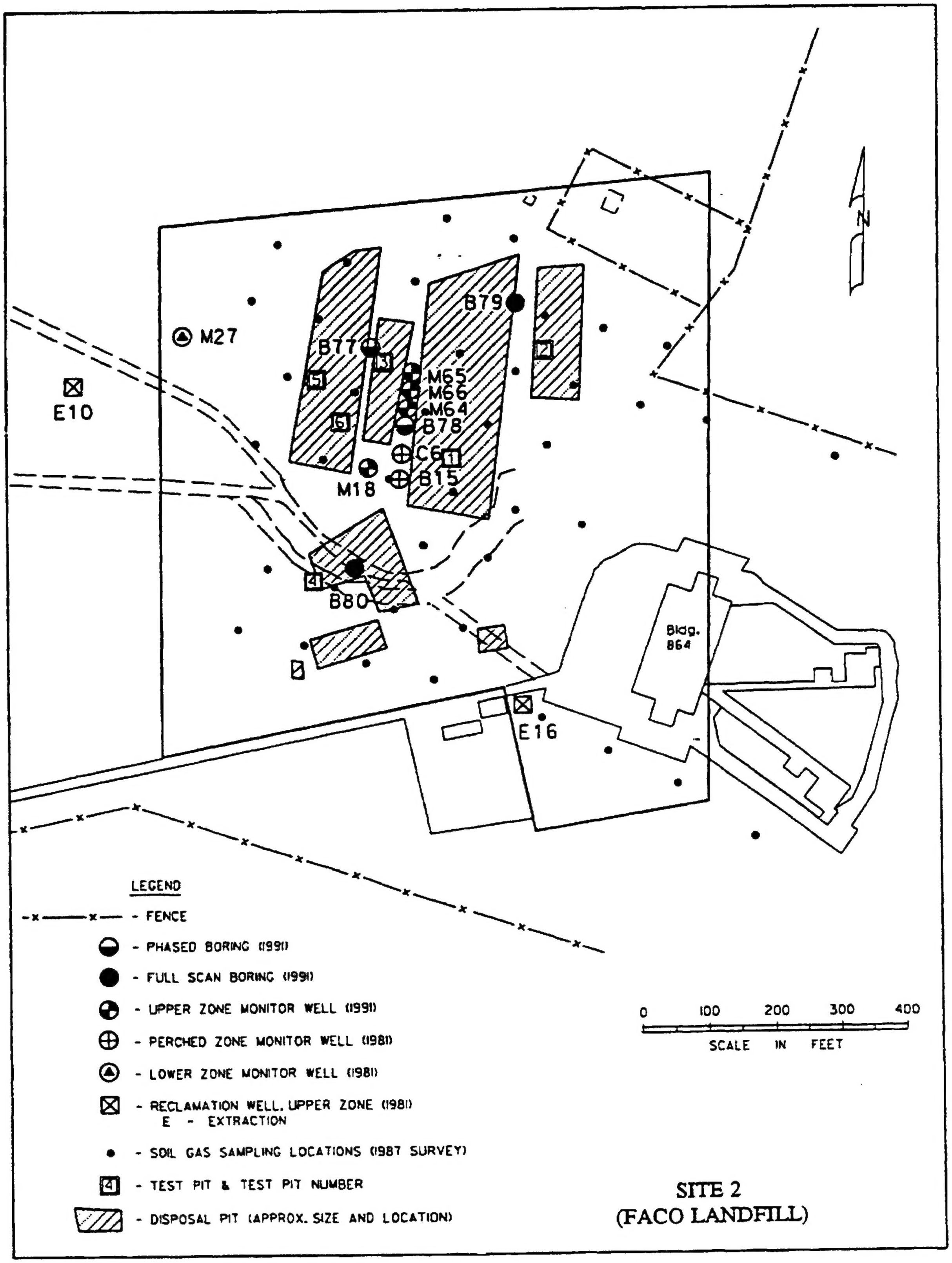


Figure 3--Site 2 (FACO Landfill) Soil Vapor Extraction (SVE) System

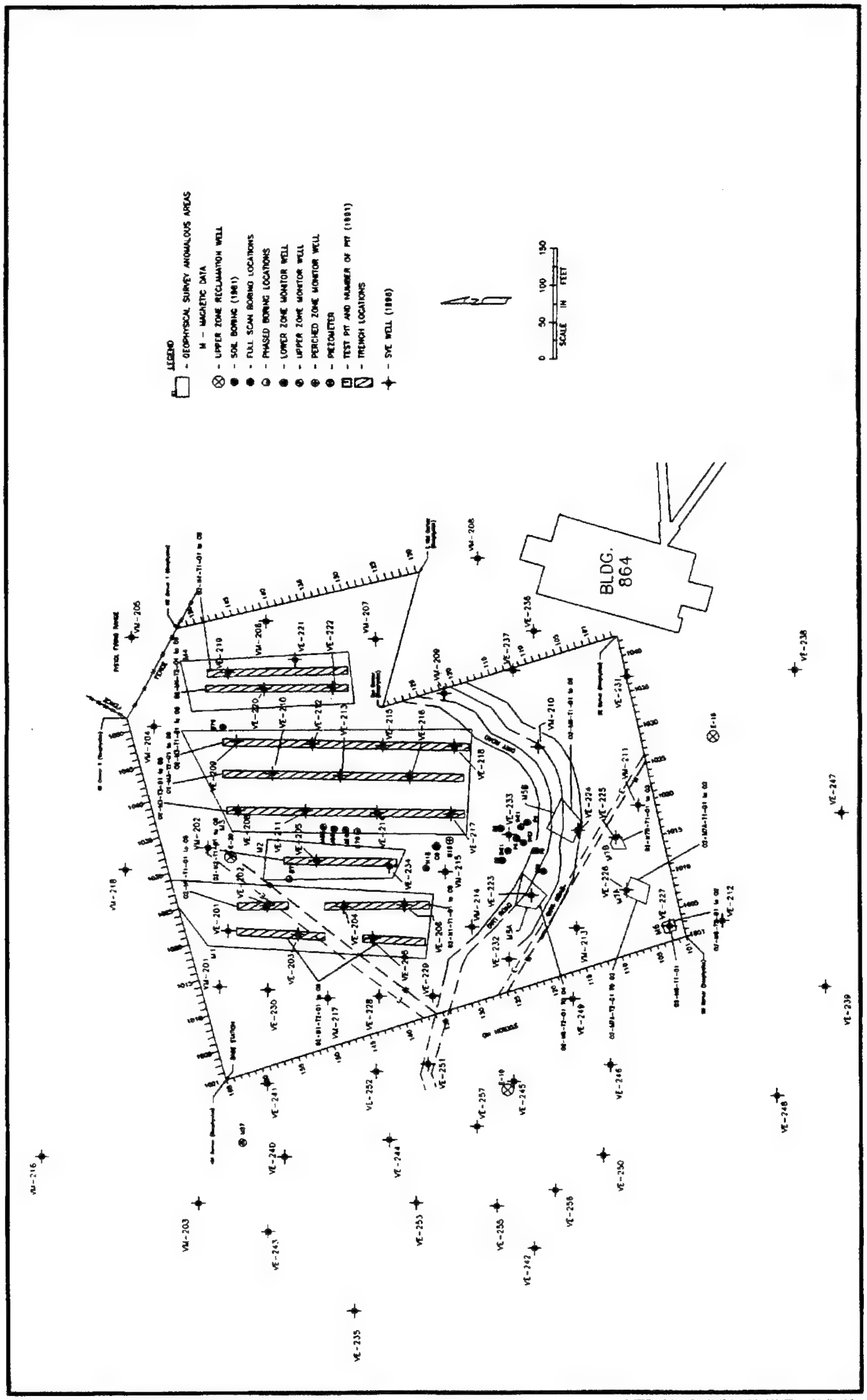
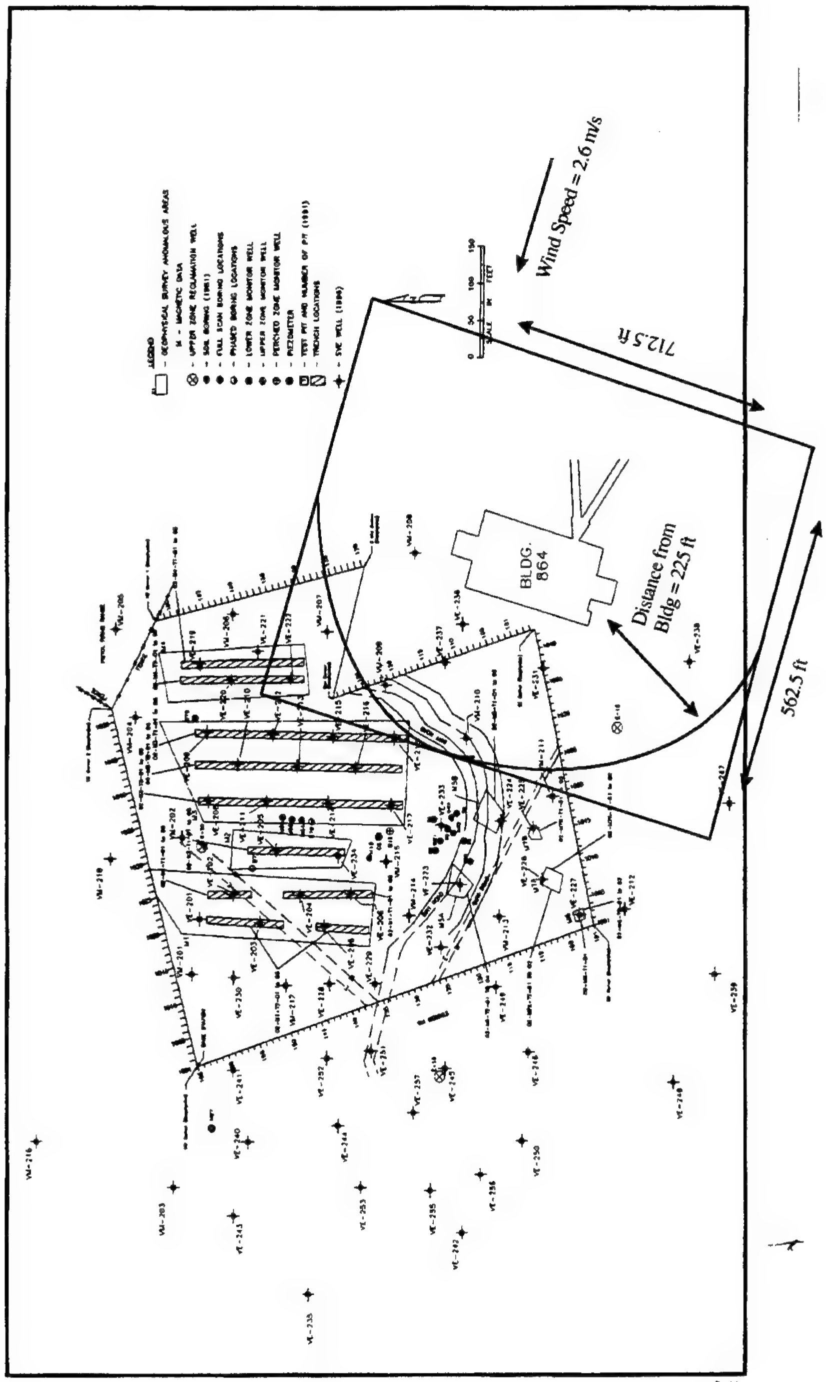


Figure 4--Site 2 Study Area (including dimensions for Box Model and radius from Bldg 864)



We also calculated the concentration using a mixing height of 2 m, which is the approximate height of an adults' breathing zone.

Flux Calculation

The flux, J, is calculated using chemical-specific physical properties for TCE, including Henry's law constant, and some site-specific parameters such as air filled soil porosity, total soil porosity, and distance from the source (groundwater) to the point of exit.

$$J = \frac{D_A C_g P_a^{10/3}}{L P_T^2}$$

where

J=flux in grams per second per square centimeter at the point of exit	***3.01E-12***
D_A=Vapor phase diffusion coefficient (cm^2/sec)	0.081[1]
C_g=Gas phase concentration of chemical (g/cm^3)[2]	3.44E-7
H=Henry's law constant ($atm\text{-}m^3/mole$)	0.00892[1]
P_a=Air filled soil porosity (unitless)	0.2985[3]
L=Distance from source to point of exit (cm)	1828.8[4]
P_T=Total soil porosity (unitless)	0.3[2]

[1] Reference 14
[2] Converted from 344 ug/L (See Appendix 1, Page 26)
[3] Reference 1
[4] Based on shallowest depth of 8 sampling ports studied, 60 BGS (See Appendix 1, Page 26)

Estimation of Indoor Air Concentration

Once the flux is calculated, the indoor air concentration can be estimated, taking into account the fraction of the floor through which soil gas can enter, the area and volume of the building, and the number of air changes the building experiences each hour.

$$C_{in} = \frac{E}{Q}$$

E = J x A x F, where E is the contaminant infiltration rate
Q = (ACH/3600)V

where

C_{in}=Estimated indoor air concentration (g/m^3)	***8.05E-8***
J=Contaminant flux estimated from source model (g/cm^2s)	3.01E-12
A=Area of building (cm^2)	47343389[1]
F=Fraction of floor through which soil gas can enter	0.001
ACH=building air changes per hour	0.5
V=volume of building (m^3)	12742.59[1]

[1] Reference 6

The guidance states that typical ACH for single family residences range from 0.5 to 1.5 with new or retrofitted energy-efficient structures generally range from 0.5 to 0.8. We chose a value of 0.5

to maximize C_{in}. Larger values would have resulted in a lower estimate of indoor air concentration.

Estimation of Outdoor Air Concentration (10 meter mixing zone height)

To estimate the outdoor concentration, we used the Box Model (Ref 16). The model estimates air concentration based on the assumption that the steady-state contaminant emissions completely mix with the air inside the "box". The box dimensions are determined by the area of the site and the height of the mixing zone. The box is ventilated by a steady flow of wind across the box. ADHS recommended a height of 10 m and an mean annual wind speed of 2.6 m/s.

$$C_{air}=10^3 \times E /(U \times W \times H)$$

where:

C_{air}=Concentration of the chemical in air (mg/m^3)	***1.98E-4***
E=Average volatile chemical emission rate for the exposure period (g/s)	1.12E-3[1]
U=Mean annual wind speed (m/s)	2.6
W=Width of the box perpendicular to the predominant wind direction (m)	217.17
H=Height of the mixing zone (m)	10
10^3=Conversion factor g to mg	10^3

[1] E is calculated by multiplying flux (g/cm^2s) by area of the box in cm^2 (712.5 ft x 562.5 ft =3.72E8 cm^2)

Estimation of Outdoor Air Concentration (2 meter mixing zone height)

For most risk assessment purposes, the height of the box is conservatively assumed to be about 2 m, the approximate height of an adult's breathing zone.

$$C_{air}=10^3 \times E /(U \times W \times H)$$

where:

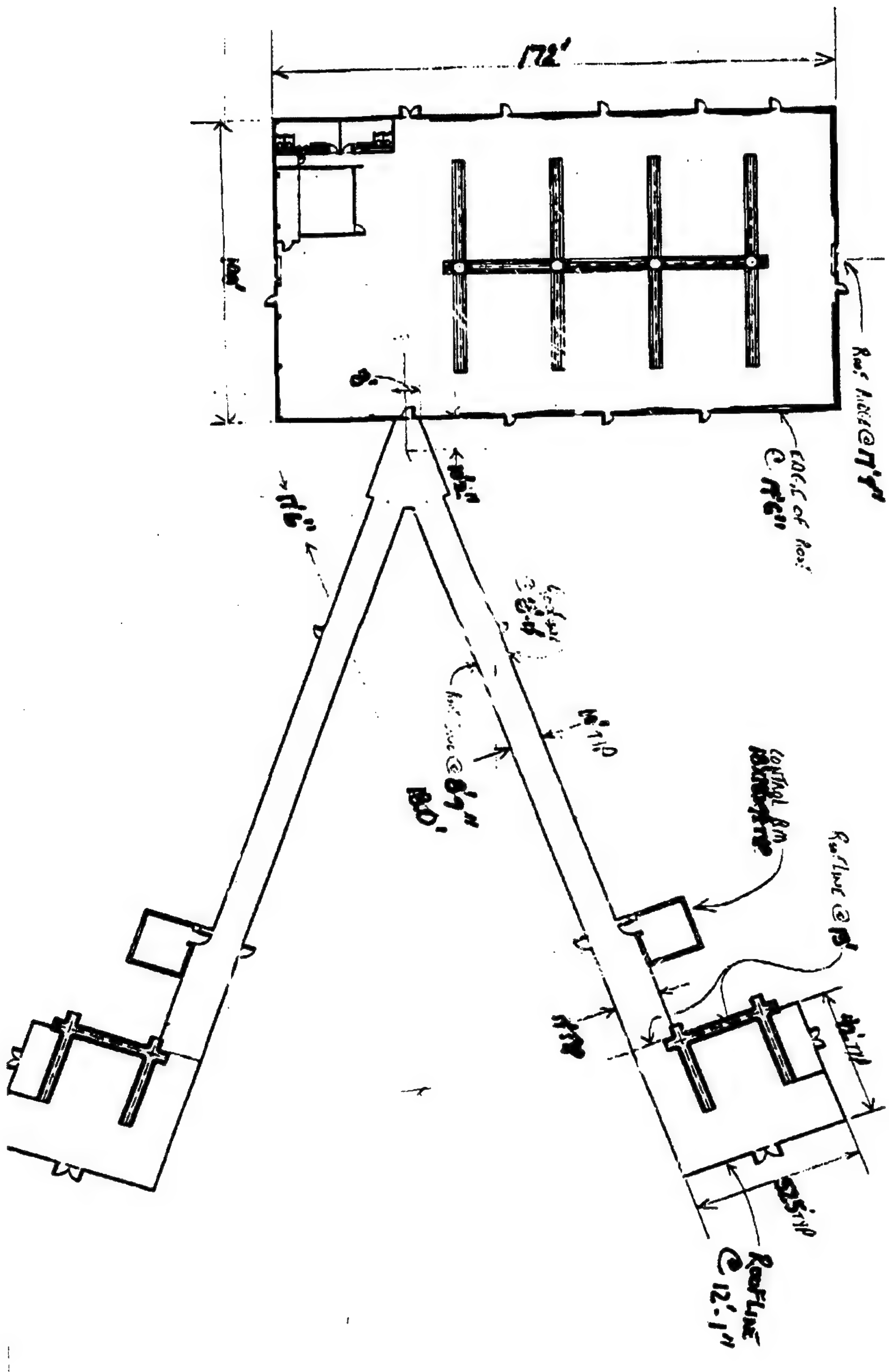
C_{air}=Concentration of the chemical in air (mg/m^3)	***9.92E-4***
E=Average volatile chemical emission rate for the exposure period (g/s)	1.12E-3[1]
U=Mean annual wind speed (m/s)	2.6
W=Width of the box perpendicular to the predominant wind direction (m)	217.17
H=Height of the mixing zone (m)	2
10^3=Conversion factor g to mg	10^3

[1] E is calculated by multiplying flux (g/cm^2s) by area of the box in cm^2 (712.5 ft x 562.5 ft =3.72E8 cm^2)

Risk Assessment Assumptions and Calculations

After we calculated potential indoor air concentration, we used EPA's "Risk Assessment Guidance for Superfund" to assess potential worker risk for cancer and non-cancer effects. These calculations involve expressions of exposure (intake) and toxicity.

Figure 5--Building 864 Dimensions



Intake

In order to assess health impact, it is necessary to characterize the exposure setting and the exposed population(s). These exposure estimates are expressed in terms of the mass of substance in contact with the body per unit body weight per unit time (e.g., mg chemical per kg body weight per day, also expressed as mg/kg-day). These exposure estimates are termed "intakes". Chemical intakes are calculated using equations that include factors for exposure concentration, contact rate, exposure frequency, exposure duration, body weight, and exposure averaging time. USEPA has issued guidance (Ref 11) for default exposure factors to reduce unwarranted variability in the exposure assessment.

Per conversations with Mr. Craig Cooper, EPA Region IX, and Mr. Will Humble, Arizona Department of Health Services (Ref 5, 7), we used an industrial/commercial scenario to evaluate health risk at Bldg 864. We used the following EPA default assumptions.

Table 1: USEPA Default Exposure Assumptions

Parameter	Value[1]
Contact rate (Inhalation rate), CR	20 m^3/day
Exposure frequency, EF	250 days/year
Exposure duration, ED	25 years
Body weight, BW	70 kg
Averaging time, AT (cancer)	70 years x 365 days/year
Averaging time, AT (non-cancer)	Exposure duration, ED, x 365 days/year

[1] Reference 11

Averaging time is calculated differently for cancer and non-cancer effects. Since USEPA assumes that any exposure to a carcinogen may cause cancer over the lifetime of the individual, USEPA uses 70 years to calculate AT for cancer and intake is referred to as a Lifetime Average Daily Dose (LADD). For non-cancer effects, the AT uses the exposure duration, since the health effect will cease when exposure ceases, and the intake is referred to as a Chronic Daily Dose (CDD).

Cancer Risks

Typically, excess cancer risk (risk above background levels) is expressed as

$$\text{Risk} = \text{Cancer Slope Factor} \times \text{Intake (LADD)},$$

where the cancer slope factor is a regulatory toxicity value approved by the agency and intake is a function of how much a person is exposed, how often exposed, body weight, and concentration of the chemical in air, soil, water, or food. This expression of risk represents an individual's personal probability of getting cancer above background levels, which now is about 33% in the United States. The USEPA strives to manage risks from hazardous waste sites in the range of 1 in 10,000 to 1 in 1,000,000 (1E-4 to 1E-6). Risks in this range may warrant additional attention, based on site specific information. Risks below 1E-6 are considered negligible and further action

is not needed. Risks above 1E-4 generally do require some additional action to mitigate or lessen exposure.

Non-cancer Health Effects

Non-cancer effects are similarly calculated and expressed as a hazard quotient, where the intake can be compared directly to the regulatory toxicity value, which in this case (air) is called a reference concentration (RfC).

Hazard Quotient = Intake (CDD)/RfC

A hazard quotient below 1 is considered safe, whereas a hazard quotient above 1 warrants further investigation and may indicate the potential for adverse health effects.

Using the general intake equation, linear low-dose cancer risk equation, and the noncancer hazard quotient equation, we calculated excess cancer risk and the hazard quotient for noncancer effects.

Table 2: Calculating Intake, Cancer Risk, and the Non-cancer Hazard Quotient

Intake Equation	Cancer Risk Equation	Hazard Quotient (noncancer)
$I = C \times \frac{CR \times EF \times ED}{BW} \times 1/AT$	$Risk = LADD \times SF_i$	HQ = CDD/RfC
where: I = intake (mg/kg body weight-day) C = chemical concentration (mg/m^3)[1] CR = contact rate (e.g., m^3/day) EF = exposure frequency ED = exposure duration BW = body weight AT = averaging time	where: LADD = Lifetime average daily dose; averaged over 70 years SF_i = inhalation cancer slope factor	where: CDD =Chronic Daily Dose RfC = reference concentration

[1]Concentration in air is converted to mg/m^3 by multiplying g/m^3 by 1000

To calculate the health risk to workers indoors, we used the assumptions listed above and the indoor air concentrations to calculate intake. Combined with the appropriate toxicity values, we then calculated lifetime cancer risks and hazard quotients (for non-cancer effects).

Table 3: Region IX Toxicity Values for TCE

Inhalation reference concentration for TCE[1]	6×10^{-3} (mg/kg-day)
Inhalation cancer slope factor for TCE[1]	6×10^{-3} (mg/kg-day)$^{-1}$

[1] Reference 15

The Lifetime Average Daily Dose, LADD, is calculated for exposure to carcinogens and is based on a lifetime exposure of 70 years. The Chronic Daily Dose, CDD, is calculated for health effects other than cancer and is based on the exposure duration, ED.

Table 4: Indoor Air Risk to Workers, Bldg 864

Default EPA Adult worker indoor air inhalation Parameters

Parameter	Unit	Value
Inhalation rate	*m3/d*	**20**
Exposure frequency	*d/y*	**250**
Exposure duration	*y*	**25**
Body weight	*kg*	**70**
Averaging time, carcinogenic	*d*	**25550**
Averaging time, non-carcinogenic	*d*	**9125**

Daily Dose (LADD or CDD) = (Conc. x CR x EF x ED) / (BW x AT)

Carcinogenic risk = LADD x SFi

Hazard Quotient = CDD /RfC

Contaminant	*Calculated Air Conc. mg/m3*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Lifetime Cancer Risk*	*Hazard Quotient*
Trichloroethylene (TCE)	8.05E-05	5.63E-06	1.58E-05	***3.38E-08***	***2.63E-03***

Using the same parameters as in Table 4 and the appropriate concentrations, the next two tables show excess risk to workers or passers-by exposed to ambient (outdoor) air at Site 2. The modeled air concentrations were obtained using the box model. Table 5 reflects a 10 meter mixing zone height as recommended by ADHS. Table 6 represents a more conservative 2 meter mixing zone height, which is the approximate height of an adult's breathing zone.

Table 5: Outdoor Air Risk to Workers, Site 2, 10 meter mixing zone height

Contaminant	*Calculated Air Conc. mg/m3*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Lifetime Cancer Risk*	*Hazard Quotient*
Trichloroethylene (TCE)	1.98E-04	1.38E-05	3.87E-05	***8.30E-08***	***6.46E-03***

Table 6: Outdoor Air Risk to Workers, Site 2, 2 meter mixing zone height

Contaminant	*Calculated Air Conc. mg/m3*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Lifetime Cancer Risk*	*Hazard Quotient*
Trichloroethylene (TCE)	9.92E-04	6.93E-05	1.94E-04	***4.16E-07***	***3.24E-02***

DISCUSSION

Results

We calculated the excess cancer risk and non-cancer hazard quotients as shown in the table below. These values are well below the standard screening level values used by the USEPA to warrant further investigation (1E-6 for excess lifetime cancer risk; 1.0 for non-cancer hazard quotient). We used many conservative assumptions in deriving our risk calculations, many of which are associated with the modeling of the air concentrations. Below is a discussion of those uncertainties.

Table 7: Summary Table, Risks to Indoor and Outdoor Workers, Site 2, Bldg 864

Worker Scenario	***Excess Lifetime Cancer Risk***	***Non-cancer Hazard Quotient***
Indoor Worker, Bldg 864	*3.38E-8*	*2.63E-3*
Outdoor Worker, Site 2 near Bldg 864 (10 meter mixing zone height)	*8.3E-8*	*6.46E-3*
Outdoor Worker, Site 2 near Bldg 864 (2 meter mixing zone height)	*4.16E-7*	*3.24E-2*

Modeling Uncertainties

Farmer Model

Per the guidance (Ref 13), the Farmer model considers flux rate of chemicals to be a result of Fickian diffusion of the vapor through the soil matrix. It ignores attenuating factors such as biodegradation and assumes the soil column to be homogeneous. Conceptual models and borehole logs from Site 2 reflect a heterogeneous soil column. It is likely that the various occurrences of clay layers from groundwater to the surface will inhibit TCE vapor diffusion, resulting in actual vapor concentrations at the surface which are lower than our modeled results.

In estimating indoor air concentration, we used F=0.001. F is the fraction of floor through which soil gas can enter. Although EPA cites references of studies using F=0.001 for buildings with slab floors, the guidance states technical literature does not support the use of assumptions based on percent cracked area of the floor and recommends "F be set to 1 in all cases". The Arizona Department of Health Services, which is conducting a risk assessment at other areas of the TIASS, is using F=0.001 (Ref 7). We agree with the state that setting F=1 is very conservative (overestimates exposures) and have chosen to use F=0.001 to be consistent with the state approach.

Building 864 Activities

We considered all areas to be exposed to the same soil gas concentrations, which will overestimate modeled air concentrations. In addition, the corridors are only used for transport, the test cells and control rooms used only during active testing. Most activity is in the main staging and assembly area (Ref 6). Using all areas of Bldg 864 in the estimated air calculation overestimates floor area and building volume, thereby overestimating indoor air concentration, excess lifetime cancer risk, and the noncancer hazard quotient.

Intake

By using USEPA guidance for calculating exposure (i.e., using default exposure parameters), we have calculated a reasonable maximum exposure (RME), which is defined as the highest exposure that is reasonably expected to occur at a site (Ref 10). The intent of the RME is to calculate a conservative exposure (i.e., well above the average case) that is still within the range of possible exposures for both current and future land-use conditions. However, because the RME is designed to be conservative, we believe actual exposures are less than we've calculated.

Box Model

We used 2.6 m/s for the mean annual wind speed at the site, per the guidance of ADHS. However, the National Weather Service at the Tucson International Airport, which is adjacent to AF Plant 44 and Site 2, advised us that the true mean annual wind speed for that area is 3.7 m/s (Ref 9). Had we applied the true mean annual wind speed to the box model, the resulting concentrations would have been less (approximately 30 percent) than what we calculated using 2.6 m/s.

CONCLUSIONS

Modeled concentrations of TCE in indoor air do not pose a health risk to workers in Bldg 864 or to workers or passers-by outside the building. The EPA and state of Arizona procedures show excess lifetime cancer risk and the noncancer hazard quotient are well below the EPA remediation goals.

RECOMMENDATIONS

Based on our evaluation of risk at this site, no further action is recommended. For the indoor exposure pathway to pose an excess cancer risk of 1E-6, soil gas concentrations would have to reach 10,320 ug/L. This is 30 times greater than the 344 ug/L concentration (the 95^{th} upper confidence level on the mean) used in this evaluation. This includes data (24 samples) for the eight SVE sampling ports within 225 feet of Bldg 864 taken between October 1996 and April 1997. None of the soil gas samples exceeded 10,320 ug/L.

For the outdoor exposure pathway, 10 meter mixing height, to pose an excess cancer risk of 1E-6, soil gas concentrations would have to reach 4100 ug/L. This is 10 times greater than the 95^{th} UCL on the mean (411 ug/L) for all 227 samples (76 sampling ports) taken between October 1996 and April 1997. Of all the samples taken during this time frame, only port P-2 exceeded 4100 ug/L (9420 ug/L on 11/21/96).

A similar comparison for non-cancer effects shows that soil gas concentrations would have to reach 130,000 ug/L and 53,000 ug/L, for the indoor and outdoor pathways respectively, to exceed a hazard quotient of 1.0.

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Appendix 1: Air Force Plant 44, SVE Data for Site 2

Air Force Plant 44--SVE Data for Site 2

Sample Port	Sample Date		TCE Result	Conc for RA (ug/L)		Depth (Shallow String), ft bgs
E-16	10/12/96		570	570		120-130
	11/22/96		133	133		
	4/10/97		107	107		
P-2	10/2/96		3000	3000		75.8-90.9
	11/21/96		9420	9420		
	4/8/97		3933	3933		
VE-201	10/21/96		64	64		60-80
	11/20/96	<	273	136.5		
	3/19/97		42	42		
	4/3/97		21	21		
VE-202	10/21/96		55	55		60-80
	11/20/96	<	273	136.5		
	4/3/97		40	40		
VE-203	10/21/96		39	39		30-60
	11/19/96	<	273	136.5		
	4/3/97		33	33		
VE-204	10/21/96		310	310		60-80
	11/20/96		226	226		
	4/7/97		153	153		
VE-205	10/21/96		33	33		60-80
	11/20/96		147	147		
	3/19/97		52	52		
	4/7/97		51	51		
VE-206	10/3/96		590	590		60-80
	11/20/96	<	273	136.5		
	3/31/97		33	33		
VE-207	8/29/96		190	190		30-60
	11/14/96	<	273	136.5		
	3/31/97		17	17		
VE-208	8/29/96		1200	1200		60-80
	11/13/96	<	273	136.5		
	3/31/97		13	13		
VE-209	8/29/96		1500	1500		60-80
	11/13/96	<	273	136.5		
	3/31/97		16	16		
VE-210	8/29/96		720	720		60-80
	11/15/96	<	273	136.5		
	3/31/97		30	30		
VE-211	8/29/96		640	640		60-80
	11/14/96	<	273	136.5		
	3/31/97		22	22		
VE-212	8/29/96		960	960		60-80

	11/14/96	<	273	136.5		
	3/31/97		23	23		
VE-213	8/29/96		160	160		30-60
	11/14/96	<	273	136.5		
	3/31/97		29	29		
VE-214	10/3/96		99	99		60-80
	11/21/96	<	273	136.5		
	3/31/97		27	27		
VE-215	10/1/96		190	190		60-80
	11/21/96		114	114		
	4/8/97		26	26		
VE-216	10/3/96		170	170		60-80
	11/21/96	<	273	136.5		
	4/8/97		38	38		
VE-217	10/1/96		53	53		60-80
	11/21/96	<	273	136.5		
	4/8/97		26	26		
VE-218	10/3/96		22	22		60-80
	11/21/96	<	273	136.5		
	4/8/97		11	11		
VE-219	8/29/96		1100	1100		60-80
	11/13/96	<	273	136.5		
	4/7/97		4	4		
VE-220	8/29/96		40	40		30-60
	11/15/96	<	273	136.5		
	3/31/97		24	24		
VE-221	8/29/96		870	870		60-80
	11/14/96	<	273	136.5		
	4/7/97		11	11		
VE-222	8/29/96		120	120		60-80
	11/14/96	<	273	136.5		
	4/7/97		10	10		
VE-223	11/9/96		110	110		10.0-15
	11/22/96	<	273	136.5		
	4/2/97		6	6		
VE-224	10/10/96		450	450		60-80
	11/22/96		272	272		
	4/2/97		2465	2465		
VE-225	10/10/96		890	890		60-80
	11/22/96	<	273	136.5		
	4/2/97		27	27		
VE-226	10/10/96	<	22	11		30-60
	11/22/96	<	273	136.5		
	4/2/97		36	36		
VE-227	10/10/96	<	22	11		60-80

	11/22/96	<	273	136.5		
	4/2/97		23	23		
VE-228	10/23/96	<	22	11		60-80
	11/20/96	<	273	136.5		
	3/28/97		24	24		
VE-229	10/21/96		26	26		60-80
	11/19/96	<	273	136.5		
	3/28/97		40	40		
VE-230	10/23/96		140	140		60-80
	11/20/96	<	273	136.5		
	4/3/97		32	32		
VE-231	10/12/96	<	22	11		60-80
	11/22/96	<	273	136.5		
	3/19/97		16	16		
	4/10/97		5	5		
VE-232	10/3/96	<	22	11		10.0-15
	11/22/96	<	273	136.5		
	3/31/97		9	9		
VE-233	10/1/96		89	89		10.0-15
	11/21/96	<	273	136.5		
	4/2/97		37	37		
VE-234	10/3/96		230	230		60-80
	11/21/96	<	273	136.5		
	3/31/97		83	83		
VE-235	8/19/96		280	280		60-80
	11/11/96		11	11		
	3/25/97		7.3	7.3		
	4/10/97		5	5		
VE-236	10/14/96		370	370		60-80
	11/22/96	<	273	136.5		
	4/7/97		15	15		
VE-237	10/3/96		46	46		60-80
	11/22/96	<	273	136.5		
	4/8/97		14	14		
VE-238	11/21/96	<	273	136.5		60-80
	4/9/97		1.9	1.9	J	
VE-239	11/21/96	<	273	136.5		60-80
	4/9/97		8	8		
VE-240	8/19/96		1400	1400		60-80
	11/11/96		20	20		
	03/26/97		8	8		
VE-241	8/19/96		2400	2400		60-80
	11/12/96	<	3	1.5		
	3/27/97		0.8	0.8	J	
VE-242	8/22/96	<	83	83		60-80

	11/12/96	<	273	136.5		
	3/27/97		8	8		
VE-243	8/19/96		400	400		60-80
	11/12/96		3	3		
	3/26/97		14	14		
VE-244	8/22/96	<	1100	1100		60-80
	11/12/96	<	273	136.5		
	3/27/97		2	2	J	
VE-245	8/19/96		970	970		60-80
	11/12/96	<	273	136.5		
	3/27/97		33	33		
VE-246	8/22/96		250	250		60-80
	11/13/96	<	273	136.5		
	3/28/97		44	44		
VE-247	11/21/96	<	273	136.5		60-80
	4/9/97		5	5		
VE-248	11/21/96	<	273	136.5		60-80
	4/9/97		10	10		
VE-249	8/22/96	<	160	160		60-80
	11/13/96		96	96		
	3/28/97		22	22		
VE-250	8/22/96		390	390		60-80
	11/13/96	<	273	136.5		
	3/28/97		2	2	J	
VE-251	10/23/96		60	60		60-80
	11/20/96	<	273	136.5		
	3/28/97		33	33		
VE-252	10/23/96		100	100		60-80
	11/20/96	<	273	136.5		
	4/3/97		16	16		
VE-253	8/19/96		820	820		60-80
	11/11/96	<	3	1.5		
	3/26/97	<	3	1.5		
VE-255	8/22/96		1400	1400		60-80
	11/12/96		207	207		
	3/27/97		12	12		
VE-256	8/22/96		1000	1000		60-80
	11/13/96	<	273	136.5		
			2	2	J	
VE-257	8/19/96		1100	1100		60-80
	11/12/96	<	273	136.5		
	3/27/97		8	8		
VM-201	10/21/96		59	59		60-80
	11/19/96	<	273	136.5		
	4/3/97		14	14		

VM-202	11/21/96	<	273	136.5		60-80
	4/9/97	<	3	1.5		
VM-203	8/19/96		270	270		60-80
	11/12/96		9	9		
	3/26/97		11	11		
VM-204	8/29/96		1000	1000		60-80
	11/13/96	<	273	136.5		
	4/7/97		1	1	J	
VM-205	11/21/96	<	273	136.5		60-80
	4/9/97		0.4	0.4	J	
VM-206	8/29/96		580	580		60-80
	11/14/96	<	273	136.5		
	4/7/97		4	4		
VM-207	8/29/96		670	670		60-80
	11/14/96	<	273	136.5		
	3/24/97		1.7	1.7	J	
	4/10/97		3	3		
VM-208	10/3/96		68	68		60-80
	11/22/96	<	273	136.5		
	4/8/97		14	14		
VM-209	10/3/96		21	21		60-80
	11/21/96		115	115		
	4/8/97		26	26		
VM-210	10/10/96		26	26		60-80
	11/22/96	<	273	136.5		
	4/2/97		189	189		
VM-211	10/11/96	<	22	11		60-80
	11/22/96	<	273	136.5		
	4/2/97		41	41		
VM-212	10/11/96		100	100		60-80
	11/22/96	<	273	136.5		
	3/19/97		49	49		
	4/10/97		25	25		
VM-213	10/9/96	<	21	10.5		10.0-15
	11/22/96	<	273	136.5		
	3/19/97		22	22		
	4/10/97		15	15		
VM-214	10/2/96		210	210		60-80
	11/22/96	<	273	136.5		
	3/31/97		138	138		
VM-215	10/2/96		120	120		60-80
	11/21/96		158	158		
	3/31/97		25	25		
VM-216	11/21/96	<	273	136.5		60-80
	4/9/97	<	3	1.5		

VM-217	10/23/96		120	120		60-80
	11/20/96	<	273	136.5		
	3/28/97		126	126		
VM-218	11/21/96	<	273	136.5		60-80
	4/9/97		9	9		

TCE concentration for wells within 200 foot radius of Building 864						
Sample Port	**Sample Date**		**TCE Result**	**Conc for Risk Assessment (ug/L)—half the detection limit for non-detects**		**Depth (Shallow String), ft bgs**
E-16	10/12/96		570	570		120-130
	11/22/96		133	133		
	4/10/97		107	107		
VE-231	10/12/96	<	22	11		60-80
	11/22/96	<	273	136.5		
	3/19/97		16	16		
	4/10/97		5	5		
VE-236	10/14/96		370	370		60-80
	11/22/96	<	273	136.5		
	4/7/97		15	15		
VE-237	10/3/96		46	46		60-80
	11/22/96	<	273	136.5		
	4/8/97		14	14		
VE-238	11/21/96	<	273	136.5		60-80
	4/9/97		1.9	1.9	J	
VM-208	10/3/96		68	68		60-80
	11/22/96	<	273	136.5		
	4/8/97		14	14		
VM-209	10/3/96		21	21		60-80
	11/21/96		115	115		
	4/8/97		26	26		
VM-210	10/10/96		26	26		60-80
	11/22/96	<	273	136.5		
	4/2/97		189	189		
			mean	***107.0***	***ug/L***	
				0.107	***ug/m3***	
				0.000107	***mg/m3***	
			95th UCL concentration			
				344	***ug/L***	
				0.344	***ug/m3***	
				0.000344	***mg/m3***	
				3.44E-07	***g/cm3***	

Appendix 2: References

REFERENCES

1. The Earth Technology Corporation, Feasibility Study Report for Air Force Plant 44, Volume IV, Appendix G, January 1995.

2. The Earth Technology Corporation, Final Risk Assessment Report for Air Force Plant 44, page 1-35, August 1993.

3. Groundwater Resources Consultants, Inc., Semi-Annual Groundwater Remediation Status Report, January through June 1995, U.S. Air Force Plant No. 44, Figure 6, September 13, 1995.

4. Ibid, Appendix C-1.

5. Personal Communication with Craig Cooper, U.S. Environmental Protection Agency, Region IX, June 6, 1996.

6. Personal Communication with Jim Craghead, Hughes Missile Systems Company, June 20, 1996.

7. Personal Communication with Will Humble, Arizona Department of Health Services, June 18, 1996.

8. Personal Communication with Will Humble, Arizona Department of Health Services, May 1 1997.

9. Personal Communication with Paul Crimmins, National Weather Service, Tucson International Airport, May 5, 1997.

10. U.S. Environmental Protection Agency, Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final, Office of Emergency and Remedial Response, Washington, D.C., December 1989b.

11. U.S. Environmental Protection Agency, Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors", Office of Emergency and Remedial Response, Washington, D.C., March 25, 1991b.

12. U.S. Environmental Protection Agency, "Supplemental Guidance to RAGS: Calculating the Concentration Term", Office of Solid Waste and Emergency Response, Publication 9285.7-081, May 1992.

13. U.S. Environmental Protection Agency, Air/Superfund National Technical Guidance Study Series: Assessing Potential Indoor Air Impacts for Superfund Sites, EPA-451/R-92-002, September 1992.

14. U.S. Environmental Protection Agency, Region IX Preliminary Remediation Goals (PRGs) Second Half 1994, August 1, 1994.

15. U.S. Environmental Protection Agency, Region IX Preliminary Remediation Goals (PRGs), August 1, 1996.

16. University of Wisconsin-Madison, "Quantifying Uncertainty in Risk Assessment And Fate and Transport Modeling", Student Handbook, March 14-15 1996, Course number 6727.